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(54) Title: PERIPHERAL CANNABINOID RECEPTOR (CB2) SELECTIVE LIGANDS

(57) Abstract: Novel polycyclic cannabinoid analogs are presented which have preferentially high affinities for the cannabinoid CB2 receptor sites. The improved receptor affinity makes these analogs therapeutically useful as medications in individuals and animals for treatment of pain, glaucoma, epilepsy, nausea associated with chemotherapy.

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PERIPHERAL CANNABINOID RECEPTOR (CB2) SELECTIVE LIGANDS

Field of the Invention

The present invention relates generally to cannabinoid compounds and is more particularly concerned with new and improved cannabinoid compounds exhibiting high binding affinities for the CB2 cannabinoid receptor, pharmaceutical preparations employing these analogs and methods of administering therapeutically effective amounts of the preparations to provide a physiological effect.

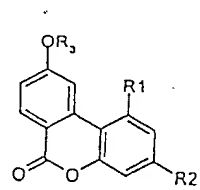
Background of the Invention

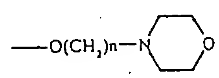
Classical cannabinoids such as the marijuana derived cannabinoid Δ^9-tetrahydrocannabinol, (Δ^9-THC) produce their pharmacological effects through interaction with specific cannabinoid receptors in the body. So far, two cannabinoid receptors have been characterized: CB1, a central receptor found in the mammalian brain and peripheral tissues and CB2, a peripheral receptor found only in the peripheral tissues. Compounds that are agonists or antagonists for one or both of these receptors have been shown to provide a variety of pharmacological effects. See, for example, Pertwee, R.G., Pharmacology of cannabinoid CB1 and CB2 receptors, Pharmacol. Ther., (1997) 74:129 - 180 and Di Marzo, V., Melck, D., Bisogno, T., DePetrocellis, L., Endocannabinoids: endogenous cannabinoid receptor ligands with neuromodulatory action, Trends Neurosci. (1998) 21:521 - 528.

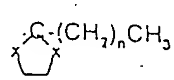
There is considerable interest in developing cannabinoid analogs possessing high affinity for the CB2 receptor. Cannabinoid analogs that preferentially stimulate the CB2 receptor, directly or indirectly, can provide clinically useful effects without affecting the subject's central nervous system. Such analogs may offer a rational therapeutic approach to a variety of disease states.

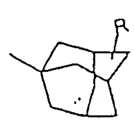
Summary of the Invention

It has now been found that certain novel cannabinoids possess improved CB2 receptor affinity over known cannabinoids. In one aspect of the invention, novel cannabinoids can be represented by the following formula and physiologically acceptable salts thereof.

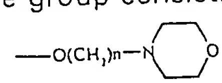


wherein R_1 is selected from the group consisting of OH; H; OCH_3; N_3; NH_2; $O(CH_2)_nN(CH_3)_2$ and  ;where n is an integer from 1 - 3;

R_2 is selected from the group consisting of $(CH_2)_nCH_3$, where n is an integer from 4 - 6; $C(CH_3)_2(CH_2)_nCH_3$, where n is an integer from 3 - 5;  where X is selected from the group consisting of C, O, S and NH and n is an integer from 3 - 5; $(CH_2)_nC{\equiv}C$ where n is an integer from 3 - 5; $C{\equiv}C(CH_2)_nCH_3$ where n is an integer from 2 - 4 and



where R is $(CH_2)_nCH_3$, and n is a maximum of 7; and

R_3 is selected from the group consisting of H; CH_3; C_2H_5; C_3H_7; C_4H_9; $O(CH_2)_nN(CH_3)_2$ and  ;where n is an integer from 1 - 3.

The novel cannabinoids are also more polar (less lipophilic) then known cannabinoids, which can improve their therapeutic usefulness in certain applications. Therefore, the novel cannabinoids described herein, and physiologically acceptable salts thereof, represent potentially useful materials for providing a physiological effect to treat pain, peripheral pain, glaucoma, epilepsy, nausea such as associated with cancer chemotherapy, cancer, neurodegenerative diseases including Multiple Sclerosis, Parkinson's Disease, Huntington's Chorea and Alzheimer's Disease, to reduce fertility; to prevent or reduce diseases associated with motor function such as Tourette's syndrome; to prevent or reduce inflammation; to provide neuroprotection and to modulate the immune system. Thus, another aspect of the invention is the administration of a therapeutically effective amount of an inventive compound, or a physiologically acceptable salt thereof, to an individual or animal to provide a physiological effect.

Brief Description of the Drawings

Figures 1 - 13 are graphs illustrating the physiological effects of the novel cannabinoid compounds.

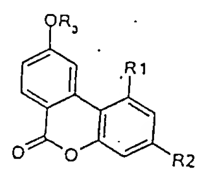
Description of Some Preferred Embodiments

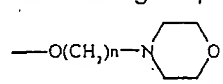
As used herein a "therapeutically effective amount" of a compound, is the quantity of a compound which, when administered to an individual or animal, results in a sufficiently high level of that compound in the individual or animal to cause a discernible increase or decrease in stimulation of cannabinoid receptors. Physiological effects that result from cannabinoid receptor stimulation include analgesia, decreased nausea resulting from chemotherapy, sedation and increased appetite. Other physiological functions include relieving intraocular pressure in glaucoma patients and suppression of the immune system. Typically, a "therapeutically effective amount" of the compound ranges from about 10 mg/day to about 1,000 mg/day.

As used herein, an "individual" refers to a human. An "animal" refers to, for example, veterinary animals, such as dogs, cats, horses and the like, and farm animals, such as cows, pigs and the like.

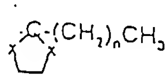
The compound of the present invention can be administered by a variety of known methods, including orally, rectally, or by parenteral routes (e.g., intramuscular, intravenous, subcutaneous, nasal or topical). The form in which the compounds are administered will be determined by the route of administration. Such forms include, but are not limited to, capsular and tablet formulations (for oral and rectal administration), liquid formulations (for oral, intravenous, intramuscular or subcutaneous administration) and slow releasing microcarriers (for rectal, intramuscular or intravenous administration). The formulations can also contain a physiologically acceptable vehicle and optional adjuvants, flavorings, colorants and preservatives. Suitable physiologically to acceptable vehicles may include, for example, saline, sterile water, Ringer's solution, and isotonic sodium chloride solutions. The specific dosage level of active ingredient will depend upon a number of factors, including, for example, biological activity of the particular preparation, age, body weight, sex and general health of the individual being treated.

The inventive compounds can generally be described with reference to the below formula and include physiologically acceptable salts thereof.

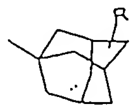


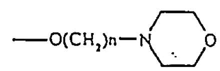
wherein R_1 is selected from the group consisting of OH; H; OCH_3; N_3; NH_2; $O(CH_2)_nN(CH_3)_2$ and  ;where n is an integer from 1 - 3;

R_2 is selected from the group consisting of $(CH_2)_nCH_3$, where n is an integer from 4 - 6; $C(CH_3)_2(CH_2)_nCH_3$, where n is an integer from 3 - 5;

 where X is selected from the group

consisting of C, O, S and NH and n is an integer from 3 - 5; $(CH_2)_nC\equiv C$ where n is an integer from 3 - 5; $C\equiv C(CH_2)_nCH_3$ where n is an integer from 2 - 4 and

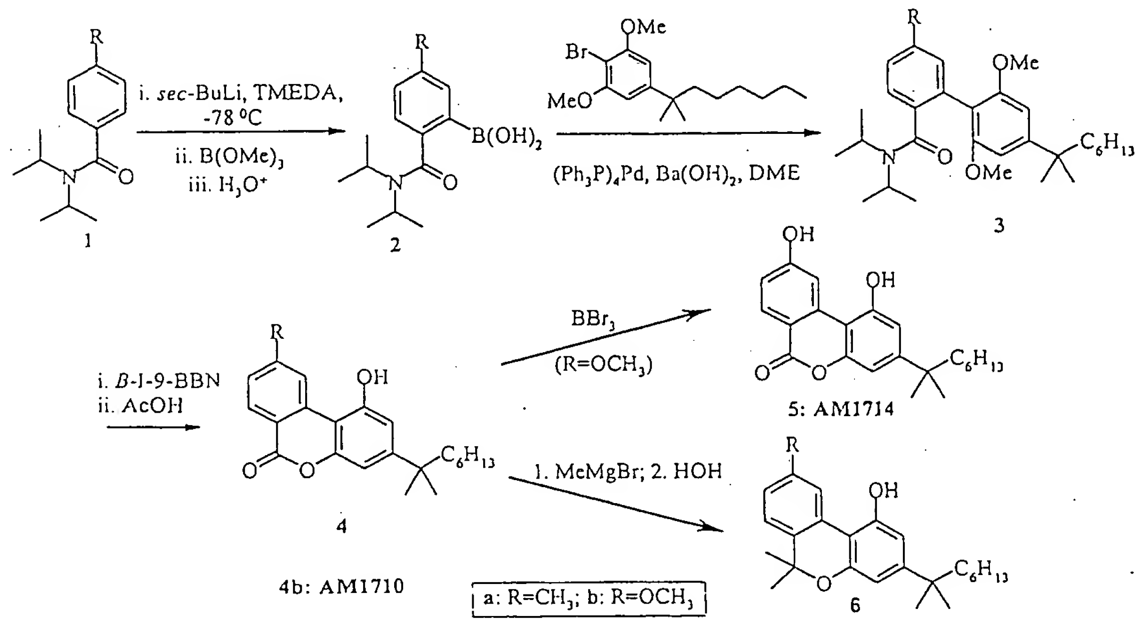
 where R is $(CH_2)_nCH_3$, and n is a maximum of 7; and

R_3 is selected from the group consisting of H; CH_3; C_2H_5; C_3H_7; C_4H_9; $O(CH_2)_nN(CH_3)_2$ and  ;where n is an integer from 1 - 3.

The following examples are given for purposes of illustration only in order that the present invention may be more fully understood. These examples are not intended to limit in any way the practice of the invention. The preparation procedures include aspects of the following references, the disclosures of which are hereby incorporated by reference.. Alo, B. I.; Kandil, A.; Patil, P. A.; Sharp, M. J.; Siddiqui, M. A.; and Snieckus, V. <u>Sequential Directed Ortho Metalation-Boronic Acid Cross-Coupling Reactions. A General Regiospecific Route to Oxygenated Dibenzo[b,d]pyran-6-ones Related to Ellagic Acid</u>, *J. Org. Chem.* 1991, *56*, 3763-3768. Beak, P.; and Brown, R. A., <u>The Tertiary Amide as an Effective Director of Ortho Lithiation</u>, *J. Org. Chem.* 1982, *47*, 34-46. Watanabe, T.; and Miyaura; Suzuki, A., <u>Synthesis of Sterically Hindered Biaryls via the Palladium Catalyzed Cross-Coupling Reaction of Arylboronic Acids or their Esters with Haloarenes</u>, *Synlett* 1992, 207-210. Morris, S.; Mechoulam, R.; and Irene, Y., <u>Halogenation of Phenols and Phenyl Ethers with Potassium Halides in the Presence of 18-Crown-6 on Oxidation with m-Chloroperbenzoic Acid</u>, *J. Chem. Soc., Perkin Trans. 1* 1987, 1423-1427. Rhee, M. H.; Vogel, Z.; Barg, J.; Bayewitch, M.; Levy, R.; Hanus, L.; Breuer, A.; and Mechoulam, R., <u>Cannabinol Derivatives: Binding to Cannabinoid Receptors and Inhibition of Adenylylcyclase</u>, *J. Med. Chem.* 1997, *40*, 3228-3233. Ludt, R. E.; Griffiths, J. S.; McGrath, K. N.; and Hauser, C. R., <u>Metalations of *N,N*-Dialkyltouamides</u>, *J. Org. Chem.* 1973, 38, 1668-1674. Novak, J.; and Salemink, C. A.,

Cannabis. Part 27. Synthesis of 8-, 10-, and 11-Oxygenated Cannabinoids, *J. Chem. Soc. Perkin Trans.* 1983, 2867-2871. Materials AM1710 and AM1714 were prepared. Material AM1710 can be represented by the above structural formula when R_1 is OH, R_2 is 1,1-dimethylheptyl and R_3 is CH_3. Material AM1714 can be represented by the above structural formula when R_1 and R_3 are each OH and R_2 is 1,1-dimethylheptyl. Materials AM1710 and AM1714 were prepared as follows.

Scheme 1



General. Proton NMR spectra were recorded on Bruker 200MHz and 500 MHz spectrometers as solutions in deuterated chloroform unless noted otherwise. Routine GC-MS analyses of the intermediates and the final products were performed on a Hewlett-Packard 6890A series gas chromatograph coupled with a mass selective detector (MSD). Tetrahydrofuran (THF) was distilled from sodium-benzophenone ketyl immediately prior to the use. Anhydrous ethylene glycol dimethyl ether (dimethoxyethane) was purchased from Aldrich Chemical Company and degassed using argon for the Suzuki biphenyl coupling reaction. Trimethylborate, tetrakis(triphenylphosphine)palladium, barium hydroxide

octahydrate, boron tribromide, and *B*-iodo-9-BBN were also purchased from Aldrich Chemical Company. Purification by flash chromatography was carried out on silica gel, grade 9385 (230-400 mesh) using solvents indicated in the parenthesis as eluents. Thin layer chromatographic analyses were carried out Whatman $60F_{254}$ polyester plates.

2-(*N,N*-Diisopropylcarboxamido)-5-methoxyphenylboronic acid (2b). Anhydrous tetrahydrofuran (210 mL) and TMEDA (8.52 mL, 56.6 mmol) was cooled to −78 °C under argon and, with stirring, 43.2 mL of a 1.3 M *sec*-butyllithium (56.2 mmol) solution was added via syringe. The yellow solution was stirred at the same temperature for about 5 min and a solution of 12 g (51.1 mmol) of 4-methoxy-*N,N*-diisopropylbenzamide in 36 mL of anhydrous THF was added in a dropwise manner. The yellow color became more intense. The reaction mixture was stirred at -78 °C for 45 min and then 17.2 mL (153.5 mmol) of trimethylborate was added when the yellow color disappeared. The mixture was allowed to warm to room temperature overnight. The pH of the mixture was adjusted to about 6.5 by addition of 5% aqueous hydrochloric acid (about 50 mL) and concentrated on a rotary evaporator. The residue was extracted with dichloromethane. The combined organic extracts were dried and solvent removed to afford a yellow foam *in vacuo* which settled to a thick viscous product. Purity of the boronic acid was checked by TLC analysis and it was used as such in the Suzuki coupling reaction.

_N,N_-Diisopropyl-5,1′,6′-trimethoxy-4′-(1,1-dimethyl)heptyl-2-biphenylcarboxamide (3b). The above boronic acid (2.41 g, 8.68 mmol, 1.1 equiv.), tetrakistriphenylphosphine palladium (546 mg, 0.47 mmol, 0.06 equiv.) and barium hydroxide octahydrate (3.72 g, 11.81 mmol, 1.5 equiv.) and dimethoxyethane (40 mL) were combined; 7.9 mL of water was added and the reaction mixture was stirred at room temperature, under argon, for 5 min. Then, a solution of 2.41 g (7.87 mmol) of the aryl bromide in 7 mL of dimethoxyethane was added with stirring and the mixture was stirred and refluxed under argon for

24 hours (h). After cooling to room temperature, the catalyst was filtered off through celite and the filtrate was concentrated on the rotary evaporator. The residue was chromatographed on silica gel (20-50% diethyl ether-petroleum ether) to afford 2.00 g (52% yield based on the amide) of the desired biphenyl. Also, 1.25 g of the aryl bromide was recovered. The yield of the biphenyl based on the recovered bromide was 94%. R_f;0.28 (50%diethyl ether-petroleum ether); ^{1}H NMR ($CDCl_3$) δ 7.28 (m, 1H), 6.75 (m, 2H), 6.49 (s, 1H), 3.80 (s, 3H), 3.72 (s, 6H), 3.52 (m, 1H), 3.15 (m, 1H), 1.50-0.90 (complex m, 11H), 1.45 (d, 3H), 1.28 (s, 6H), 1.05 (d, 3H), 0.84 (overlapping pattern, 6H), 0.52 (d, 3H). HRMS Calcd for $C_{31}H_{47}NO_4$ 497.7092, Found 497.7095.

3-(1,1-Dimethylheptyl)-1-hydroxy-9-methoxy-6*H*-dibenzo[*b,d*]pyran-6-one (4b). The biphenyl intermediate (500 mg, 1 mmol) was dissolved in 10 mL of dry dichloromethane and 4 mL of a 1 M solution of *B*-I-9-BBN (4 mmol) in hexanes was added via syringe. The reaction mixture was stirred at room temperature for 4 h. Then, most of the dichloromethane was removed and the residue was dissolved in diethyl ether and 0.24 mL of ethanolamine was added. The mixture was allowed to stir at room temperature for 2 h; the precipitate was filtered off and the filtrate was concentrated. The residue was dissolved in 5 mL of glacial acetic acid and refluxed for 5 h. The solution was cooled to room temperature, diluted with water and extracted with diethyl ether. The ether extract was dried and ether evaporated. TLC of the residue indicated only one product which was purified by chromatography on silica gel (50% diethyl ether-petroleum ether) to afford 272 mg of a white solid. It was not the expected 1,9-dihydroxy product but rather had a methoxy group at C-9 position as seen by proton NMR spectroscopy. The structure was confirmed by x-ray crystallography: m.p. 149-151 °C; R_f;0.44 (50%diethyl ether-petroleum ether); ^{1}H NMR δ 8.51 (m, 1H), 8.35 (d, 1H), 7.03 (m, 1H), 6.90 (s, 1H), 6.73 (s, 1H), 6.57 (s, 1H), 3.95 (s, 3H), 2.01-0.95 (series of m, 10H), 1.26 (s, 6H), 0.81 (t, J=6.6 Hz, 3H); Anal. calcd. for $C_{23}H_{28}O_4$ 74.97% C, 7.66% H; Found 74.75% C, 7.39% H.

3-(1,1-Dimethylheptyl)-1,9-dihydroxy-6*H*-dibenzo[*b,d*]pyran-6-one (5).

3-(1,1-Dimethylheptyl)-1-hydroxy-9-methoxy-6*H*-dibenzo[*b,d*]pyran-6-one (4b) (200 mg, 0.54 mmol) was dissolved in 12 mL of dry dichloromethane, 2 mL of a 1M solution of boron tribromide in dichloromethane (2 mmol) was added and the resulting mixture was stirred at room temperature for 3 days. Water was added and the mixture was extracted with diethyl ether. The organic extract was dried and rotary evaporated. The residue was chromatographed on silica gel (50% ethyl.ether-petroleum ether) to afford 150 mg of a flaky off-white foam: m.p. 103-108 °C; R_f;0.28 (50%diethyl ether-petroleum ether); ^{1}H NMR δ 8.60 (m, 1H), 8.35 (d, 1H), 7.05 (d, 1H), 6.90 (s, 1H), 6.73 (s, 1H), 6.10 (br s, 2H), 1.70-0.98 (series of m, 10H), 1.27 (s, 6H), 0.82 (t, J=6.6 Hz, 3H); Anal. calcd. for $C_{23}H_{28}O_4$ 74.55% C, 7.39% H; Found 72.70% C, 7.25% H.

3-(1,1-Dimethylheptyl)-9-methoxy-6,6-trimethyl-6*H*-dibenzo[*b,d*]pyran-1-ol (6b). As described above, starting from 3-(1,1-dimethylheptyl)-1-hydroxy-9-methoxy-6*H*-dibenzo[*b,d*]pyran-6-one (4b) (30 mg, 0.082 mmol) was obtained 25.7 mg (82%) of the title compound as a viscous oil. R_f;0.22 (10%diethyl ether-petroleum ether); ^{1}H NMR δ 7.72 (m, 1H), 7.15 (m, 1H), 6.80 (m, 1H), 6.57 (d, 1H), 6.40 (d, 1H), 5.20 (s, 1H), 3.83 (s, 3H), 1.59 (s, 6H), 1.71-1.10 (complex m, 11H), 1.23 (s, 6H), 0.82 (t, J=6.7 Hz, 3H); HRMS calcd. for $C_{25}H_{34}O_3$ 382.5357, Found 382.5361.

Single-crystal X-ray Diffraction Analysis of 4a and 4b

Analogue 4b $C_{23}H_{28}O_4$, F.W. = 368.45, triclinic space group, a = 6.768(2), b = 8.794(3), c = 17.880(5) Å, a = 96.68(2), b = 99.74(1), g = 92.50(2)_, V = 1039.5(5) Å^3, Z = 2, r_{calc} = 1.177 mg mm^{-3}, /(Cu Ka) = 1.54178 Å, m = 0.635 mm^{-1}, F(000) = 396, T = 295°K. The following parameters are common to (4a) and (4b) and where different they are indicated by enclosure in brackets.

A clear colorless 0.80 x 0.36 x 0.10 [0.48 x 0.21 x 0.14] mm crystal was used for data collection on an automated Bruker P4 diffractometer

equipped with an incident beam monochromator. Lattice parameters were determined from 40[34] centered reflections within 7 < 2q < 50_ [6 < 2q < 56_]. The data collection range had a $\{(\sin q)/l\}_{max}$ = 0.55. Three standards, monitored after every 97 reflections, exhibited random variations with devs. up to ±2.5 [1.9]% during the data collection. A set of 3067 [3088] reflections was collected in the q/2q scan mode, and *w* scan rate (a function of count rate) from 7.5 _/min. to 30.0_/min. . There were 2739 [2767] unique reflections. Corrections were applied for Lorentz, polarization, and absorption effects. The structure was solved with SHELXTL and refined with the aid of the SHELX97 system of programs . The full-matrix least-squares refinement on F^2 varied 312 [248] parameters: atom coordinates and anisotropic thermal parameters for all non-H atoms. H atoms were included using a riding model [coordinate shifts of C applied to attached H atoms, C-H distances set to 0.96 to 0.93 Å, H angles idealized, U_{iso}(H) were set to 1.2 to 1.5 U_{eq}(C). Final residuals were R 1 = 0.087 [0.086] for the 1572[2045] observed data with $F_o > 4s(F_o)$ and 0.138[0.107] for all data. Final difference Fourier excursions of 0.20 and -0.29 [0.40 and -0.27]eÅ^{-3}.

In 4a the hydrocarbon chain group is disordered such that the atoms may be located on an alternate position along the chain with occupancies of 0.62 and 0.38 for the major and minor positions. There is evidence that 4b is also disordered but the disorder could not be modeled with only a major and minor form. Tables of coordinates, bond distances and bond angles, and anisotropic thermal parameters, have been deposited with the Crystallographic Data Centre, Cambridge, CB2, 1EW, England.

Cannabinoid Mediated Antinociception.

Method. Male Sprague-Dawley rats (Harlan; Indianapolis, IN) 200 - 300 grams at time of testing, were maintained in a climate-controlled room on a 12-h light/dark cycle (lights on at 06:00 h) and food and water were available ad libitum. All of the testing was performed in accordance with the policies and recommendations of the International Association for the Study of Pain (IASP)

and the National Institutes of Health (NIH) guidelines for the handling and use of laboratory animals and received approval from the Institutional Animal Care and Use Committee (IACUC) of the University of Arizona.

All drugs were dissolved in dimethyl sulfoxide (DMSO) and were injected subcutaneously in the plantar surface of the hindpaw in a total volume of 50 μl. DMSO given in hindpaw at this volume had no effect. The method of Hargreaves, K.; Dubner, R.; Brown, F.; Flores, C.; and Joris, J., A New Sensitive Method for Measuring Thermal Nociception in Cutaneous Hyperalgesia. *Pain*, 1988, *32*, 77-88, the disclosure of which is hereby incorporated by reference, was employed to assess paw-withdrawal latency to a thermal nociceptive stimulus. Rats were allowed to acclimate within Plexiglas enclosures on a clear glass plate maintained at 30°C. A radiant heat source (i.e., high intensity projector lamp) was activated with a timer and focused onto the plantar surface of the hindpaw. Paw-withdrawal latency was determined by a photocell that halted both lamp and timer when the paw was withdrawn. The latency to withdrawal of the paw from the radiant heat source was determined both before and after drug or vehicle administration. A maximal cut-off of 40 sec was employed to prevent tissue damage. As shown in Figures 1 - 13, administration of compound AM1714 produced notable physiological effects in test animals including analgesia.

Materials AM1710 and AM1714 were tested for CB2 receptor binding affinity and for CB1 receptor affinity (to determine selectivity for the CB2 receptor). As used herein, "binding affinity" is represented by the IC_{50} value which is the concentration of an analog required to occupy the 50% of the total number (Bmax) of the receptors. The lower the IC_{50} value, the higher the binding affinity. As used herein an analog is said to have "binding selectivity" if it has higher binding affinity for one receptor compared to the other receptor; e.g. a cannabinoid analog which has an IC_{50} of 0.1 nM for CB1 and 10 nM for CB2, is 100 times more selective for the CB1 receptor. The binding affinities (K_i) are expressed in nanomoles (nM).

For the CB1 receptor binding studies, membranes were prepared from rat forebrain membranes according to the procedure of P.R. Dodd et al, A Rapid Method for Preparing Synaptosomes: Comparison with Alternative Procedures, Brain Res., 107 - 118 (1981). The binding of the novel analogues to the CB1 cannabinoid receptor was assessed as described in W.A. Devane et al, Determination and Characterization of a Cannabinoid Receptor in a Rat Brain, Mol. Pharmacol., 34, 605 - 613 (1988) and A. Charalambous et al, 5'-azido Δ^8-THC: A Novel Photoaffinity Label for the Cannabinoid Receptor, J. Med. Chem., 35, 3076 - 3079 (1992) with the following changes. The above articles are incorporated by reference herein.

Membranes, previously frozen at -80°C, were thawed on ice. To the stirred suspension was added three volumes of TME (25mM Tris-HCl buffer, 5 mM $MgCl_2$ and 1 mM EDTA) at a pH 7.4. The suspension was incubated at 4°C for 30 min. At the end of the incubation, the membranes were pelleted and washed three times with TME.

The treated membranes were subsequently used in the binding assay described below. Approximately 30 μg of membranes were incubated in silanized 96-well microtiter plate with TME containing 0.1% essentially fatty acid-free bovine serum albumin (BSA), 0.8 nM [^{3}H] CP-55,940, and various concentrations of test materials at 200 °C for 1 hour. The samples were filtered using Packard Filtermate 196 and Whatman GF/C filterplates and washed with wash buffer (TME) containing 0.5% BSA. Radioactivity was detected using MicroScint 20 scintillation cocktail added directly to the dried filterplates, and the filterplates were counted using a Packard Instruments Top-Count. Nonspecific binding was assessed using 100 nM CP-55,940. Data collected from three independent experiments performed with duplicate determinations was normalized between 100% and 0% specific binding for [^{3}H] CP-55,940, determined using buffer and 100 nM CP-55,940. The normalized data was analyzed using a 4-parameter nonlinear logistic equation to yield IC_{50} values. Data from at least two independent experiments performed in duplicate was used to calculate IC_{50} values which were converted to K_i values using the using the

assumptions of Cheng et al, Relationship Between the Inhibition Constant (K_i) and the concentration of Inhibitor which causes 50% Inhibition (IC_{50}) of an Enzymatic Reaction, Biochem. Pharmacol., 22, 3099-3102, (1973), which is incorporated by reference herein.

For the CB2 receptor binding studies, membranes were prepared from frozen mouse spleen essentially according to the procedure of P.R. Dodd et al, A Rapid Method for Preparing Synaptosomes: Comparison with Alternative Procedures, Brain Res., 226, 107 - 118 (1981) which is incorporated by reference herein. Silanized centrifuge tubes were used throughout to minimize receptor loss due to adsorption. The CB2 binding assay was conducted in the same manner as for the CB1 binding assay. The binding affinities (K_i) were also expressed in nanomoles (nM).

AM1710 exhibited a CB2 affinity of 0.49 nM and about a 750-fold CB2 selectivity over CB1. Other cannabinoid analogs have been reported that show some selectivity for the CB2 receptor. However the inventive analogs described herein have a surprisingly high selectivity for the CB2 receptor that is higher than known analogs.

The physiological and therapeutic advantages of the inventive materials can be seen from the above disclosure and also with additional reference to the following references, the disclosures of which are hereby incorporated by reference. Arnone M., Maruani J., Chaperon P, *et al*, Selective inhibition of sucrose and ethanol intake by SR141716, an antagonist of central cannabinoid (CB1) receptors, Psychopharmacal, (1997) 132, 104-106. Colombo G, Agabio R, Diaz G. et al: Appetite suppression and weight loss after the cannabinoid antagonist SR141716. Life Sci. (1998) 63-PL13-PL117. Simiand J, Keane M, Keane PE, Soubrie P: SR 141716, A CB1 cannabinoid receptor antagonist, selectively reduces sweet food intake in marmoset. Behav. Pharmacol (1998) 9:179-181. Brotchie JM: Adjuncts to dopamine replacement a pragmatic approach to reducing the problem of dyskinesia in Parkinson's disease. Mov. Disord. (1998) 13:871-876. Terranova J-P, Storme J-J Lafon N et al: Improvement of memory in rodents by the selective CB1 cannabinoid receptor

antagonist, SR 141716. Psycho-pharmacol (1996) 126:165-172. Hampson AL Grimaldi M. Axpirod J. Wink D: Cannabidiol and (-) Δ^9 tetrahydrocannabinol are neuroprotective antioxidants. Proc. Natl Acad Sci. USA (1998) 9S:8268-8273. Buckley NE, McCoy KI, Mpzey E et al Immunomodulation by cannabinoids is absent in mice deficient for the cannabinoid CB_2 receptor. Eur. J Pharmacol (2000) 396:141-149. Morgan Dr: Therapeutic Uses of Cannabis. Harwood Academic Publishers, Amsterdam. (1997). Joy JE, Wagtson SJ, Benson JA: Marijuana and Medicine Assessing the Science Base. National Academy Press, Washington, DC, USA (1999). Shen M. Thayer SA: Cannabinoid receptor agonists protect cultured rat hippocampal neurons from excitotoxicity. Mol. Pharmacol (1996) 54:459-462. DePetrocellis L, Melck D, Palmisano A. et al: The endogenous cannabinoid anandamide inhibits human breaast cancer cell proliferation. Proc Natl. Acad. Sci USA (1998) 95:8375-8380. Green K. Marijuana smoking vs. cannabinoids for glaucoma therapy. Arch. Ophibalmol. (1998) feb 433-1437. Hemming M, Yellowlees PM, Effective treatment of Tourette's syndrome with marijuana. J. Psychopharmacol, (1993) 7:389-391. Muller-Vahl KB, Schneider U, Kolbe H, Emrich, HM. Treatment of Tourette's syndrome with delta-9-tetrahydrocannabinol. Am. J. Psychiat. (1999) 156-195. Muller-Vahl KB, Kolbe H, Schneider U, Emrich, HM Cannabis in movement disorders. Porsch. Kompicmentarmed (1999) 6 (suppl. 3) 23-27. Consroe P, Musty R, Rein J, Tillery W, Pertwee R. The perceived effects of smoked cannabis on patents with multiple sclerosis, Eur. Neurol. (1997) 38-44-48. Pinnegan-Ling D, Musty R. Marinol and phantom limb pain: a case study. Proc Inv. Cannabinoid Rea. Sec. (1994):53. Brenneisen R, Pgli A, Elsohly MA, Henn V. Spiess Y: The effect of orally and rectally administered Δ^{9-} tetrahydrocannabinol on spasticity, a pilot study with 2 patients. Int. J. Clin Pharmacol Ther. (1996) 34:446-452. Martyn CN. Illis LS, Thom J. Nabilone in the treatment of multiple sclerosis. Lancet (1995) 345:579. Maurer M, Henn V, Dittrich A, Hofmann A. Delta-9-tetrahydrocannabinol shows antispastic and analgesic effects in a single case double-blind trial. Eur. Arch. Psychiat. Clin. Neurosci. (1990), Z40:1-4. Herzberg U, Eliav E, Bennett GJ, Kopin IJ: The analgesic effects of R(+) WIN 55,212-2

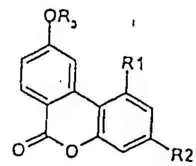
mesylate, a high affinity cannabinoid agonist in a rare model of neuropathic pain. Neurosci. Letts. (1997) 221:157-160. Richardson JD, Kilo S. Hargreaves KM, Cannabinoids reduce dryperalgesia and inflammation via interaction with peripheral CB1 receptors. Pain (1998) 75:111-119. Ricardson JD, Aanonsen I, Hargreaves KM: Antihyperalgesic effects of a spinal cannabinoids. Eur. J. Pharmacol. (1998) 346:145-153. Calignano A, La Rana G. Diuffrida A, Piomelli D: Control of pain initiation by endogenous cannabinoids. Nature (1998) 394:277-291. Wagner JA, Varga K, Jarai Z, Kunos G: Mesenteric vasodilation mediated by endothelia anandamide receptors. Hypertension (1999) 33:429-434. Schuel, H., Burkman, L.J., Picone, R.P., Bo, T., Makriyannis, A., Cannabinoid receptors in human sperm. Mol. Biol. Cell., (1997) (8), 325a.

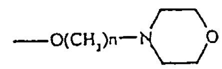
The inventive analogs described herein, and physiologically acceptable salts thereof, have high potential when administered in therapeutically effective amounts for providing a physiological effect useful to treat pain, peripheral pain, glaucoma, epilepsy, nausea such as associated with cancer chemotherapy, cancer, neurodegenerative diseases including Multiple Sclerosis, Parkinson's Disease, Huntington's Chorea and Alzheimer's Disease, to reduce fertility; to prevent or reduce diseases associated with motor function such as Tourette's syndrome; to prevent or reduce inflammation; to provide neuroprotection and to modulate the immune system. Thus, another aspect of the invention is the administration of a therapeutically effective amount of an inventive compound, or a physiologically acceptable salt thereof, to an individual or animal to provide a physiological effect.

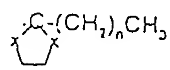
Those skilled in the art will recognize, or be able to ascertain with no more than routine experimentation, many equivalents to the specific embodiments of the invention disclosed herein. Such equivalents are intended to be encompassed by the scope of the invention.

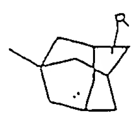
What Is Claimed Is:

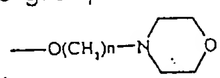
1. A compound of the formula :



wherein R_1 is selected from the group consisting of OH; H; OCH_3; N_3; NH_2; $O(CH_2)_nN(CH_3)_2$ and  ;where n is an integer from 1 - 3;

R_2 is selected from the group consisting of $(CH_2)_nCH_3$, where n is an integer from 4 - 6; $C(CH_3)_2(CH_2)_nCH_3$, where n is an integer from 3 - 5;  where X is selected from the group consisting of C, O, S and NH and n is an integer from 3 - 5; $(CH_2)_nC{\equiv}C$ where n is an integer from 3 - 5; $C{\equiv}C(CH_2)_nCH_3$ where n is an integer from 2 - 4 and

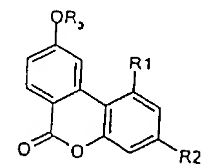
 where R is $(CH_2)_nCH_3$, and n is a maximum of 7; and

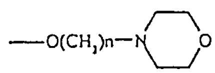
R_3 is selected from the group consisting of H; CH_3; C_2H_5; C_3H_7; C_4H_9; $O(CH_2)_nN(CH_3)_2$ and  ;where n is an integer from 1 - 3.

2. The compound of claim 1 wherein R_1 is OH; $R_2$is 1,1-dimethylheptyl and R_3 is CH_3.

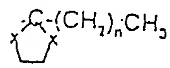
3. The compound of claim 1 wherein R_1 and R_3 are each OH and $R_2$is 1,1-dimethylheptyl.

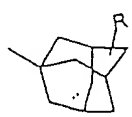
4. A method of preferentially stimulating the CB2 receptors in an individual or animal comprising administering to the individual or animal a therapeutically effective amount of a compound having the formula:

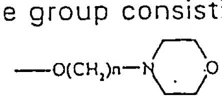


wherein R_1 is selected from the group consisting of OH; H; OCH_3; N_3; NH_2; $O(CH_2)_nN(CH_3)_2$ and  ;where n is an integer from 1 - 3;

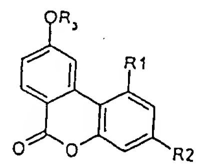
R_2 is selected from the group consisting of $(CH_2)_nCH_3$, where n is an integer from 4 - 6; $C(CH_3)_2(CH_2)_nCH_3$, where n is an integer from 3 - 5;

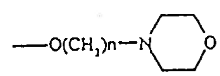
 where X is selected from the group consisting of C, O, S and NH and n is an integer from 3 - 5; $(CH_2)_nC{\equiv}C$ where n is an integer from 3 - 5; $C{\equiv}C(CH_2)_nCH_3$ where n is an integer from 2 - 4 and

 where R is $(CH_2)_nCH_3$, and n is a maximum of 7; and

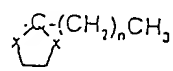
R_3 is selected from the group consisting of H; CH_3; C_2H_5; C_3H_7; C_4H_9; $O(CH_2)_nN(CH_3)_2$ and  ;where n is an integer from 1 - 3.

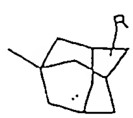
5. A pharmaceutical composition containing a therapeutically effective amount of a compound having the formula:



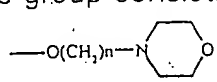
wherein R_1 is selected from the group consisting of OH; H; OCH_3; N_3; NH_2; $O(CH_2)_nN(CH_3)_2$ and  ;where n is an integer from 1 - 3;

R_2 is selected from the group consisting of $(CH_2)_nCH_3$, where n is an integer from 4 - 6; $C(CH_3)_2(CH_2)_nCH_3$, where n is an integer from 3 - 5;

 where X is selected from the group consisting of C, O, S and NH and n is an integer from 3 - 5; $(CH_2)_nC{\equiv}C$ where n is an integer from 3 - 5; $C{\equiv}C(CH_2)_nCH_3$ where n is an integer from 2 - 4 and



where R is $(CH_2)_nCH_3$, and n is a maximum of 7; and

R_3 is selected from the group consisting of H; CH_3; C_2H_5; C_3H_7; C_4H_9; $O(CH_2)_nN(CH_3)_2$ and  ;where n is an integer from 1 - 3.

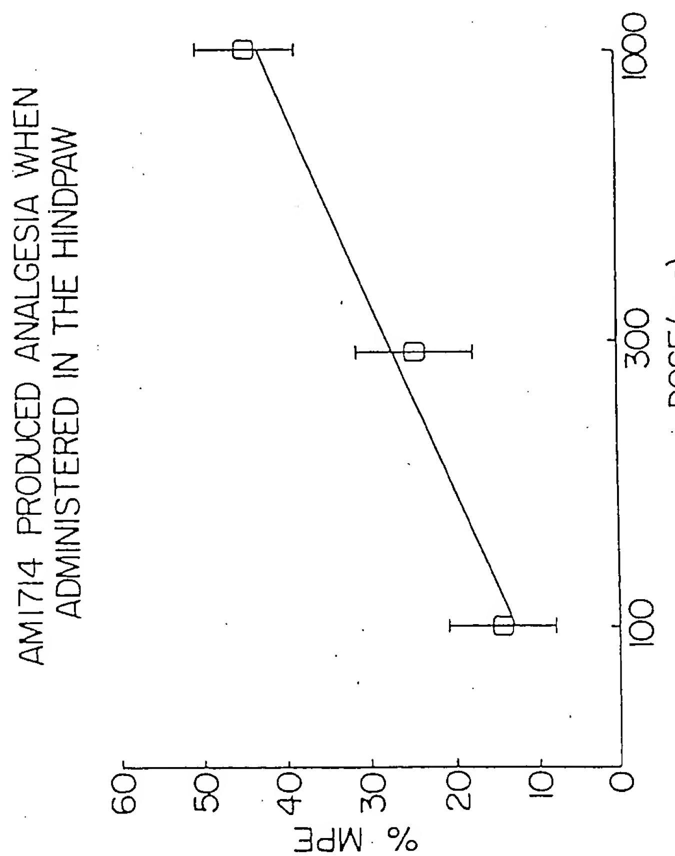

AM1714 PRODUCED ANALGESIA WHEN
ADMINISTERED IN THE HINDPAW
% MPE
0
10
20
30
40
50
60
100
300
1000
DOSE (μg)

FIG. 1

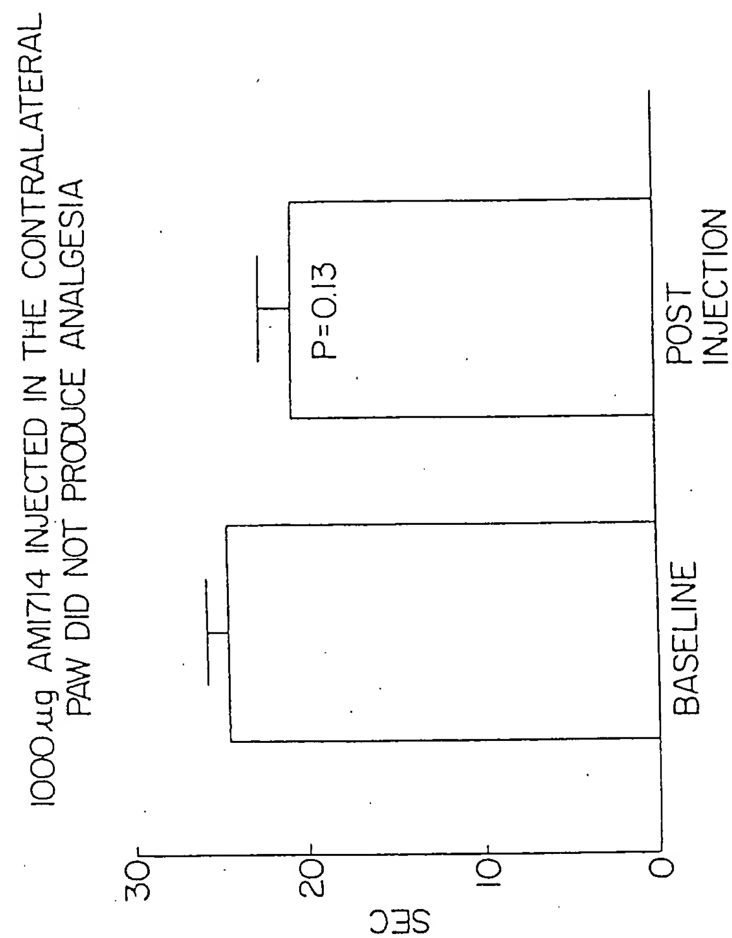

1000μg AMI714 INJECTED IN THE CONTRALATERAL PAW DID NOT PRODUCE ANALGESIA
SEC
30
20
10
0
P=0.13
BASELINE
POST INJECTION

FIG.2

300µg AM251 (A SELECTIVE CB1 ANTAGONIST) ADMINISTERED IN THE HINDPAW DID NOT BLOCK THE ANALGESIC EFFECTS OF INTRAPLANTAR 1000µg AM1714

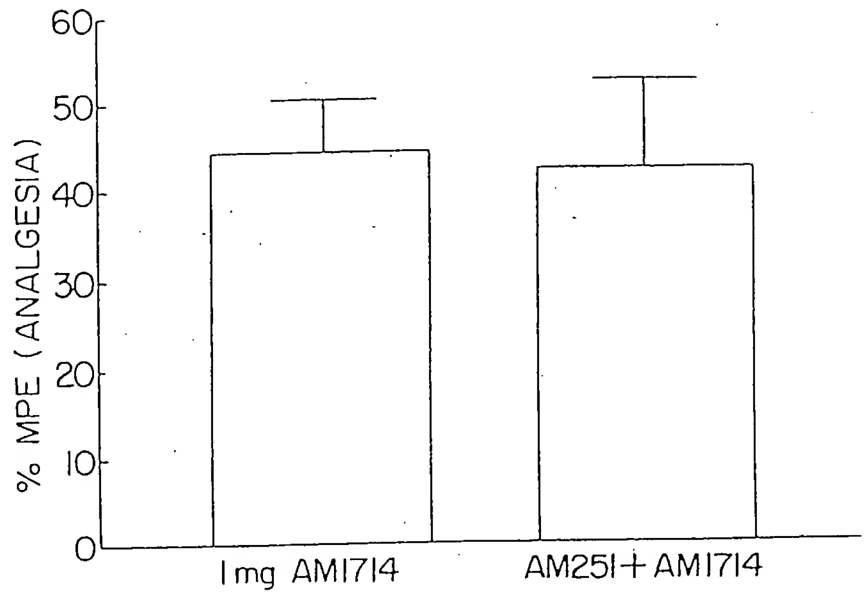


FIG.3

300µg AM630(A SELECTIVE CB2 ANTAGONIST)ADMINISTERED IN THE HINDPAW BLOCKED THE ANALGESIC EFFECTS OF INTRAPLANTAR 1mg AM1714

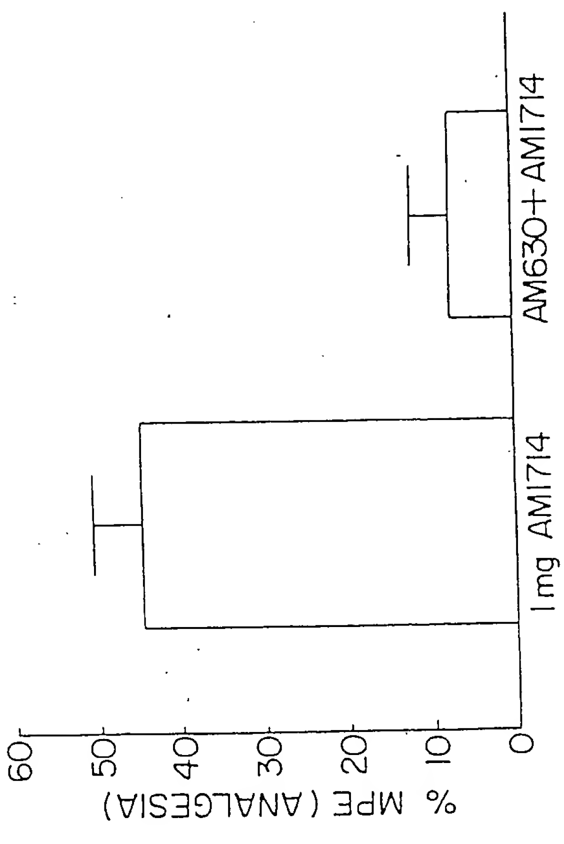


FIG. 4

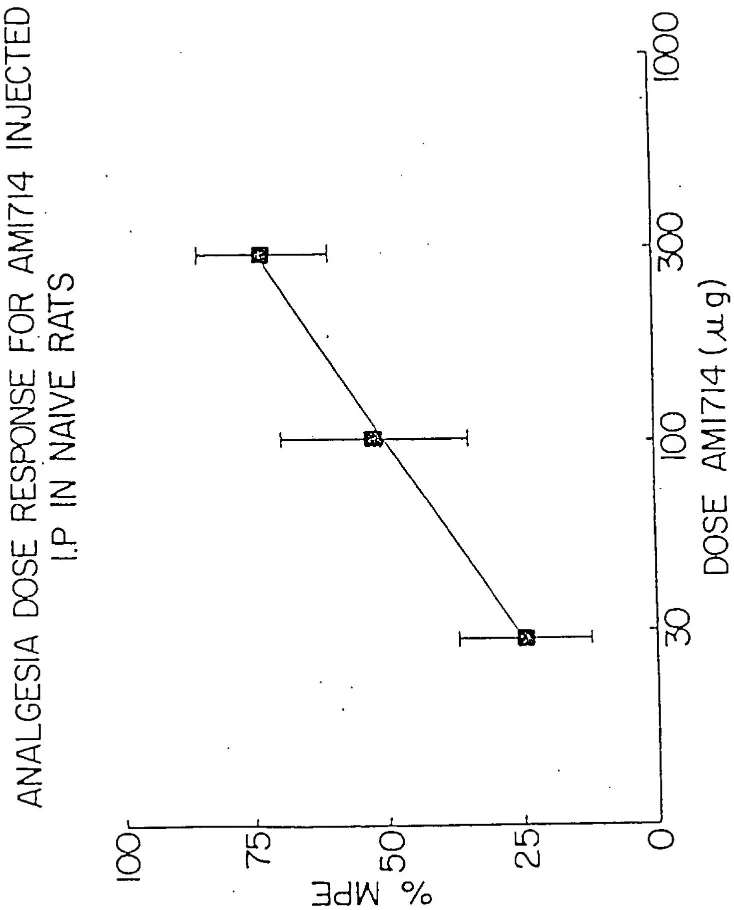

ANALGESIA DOSE RESPONSE FOR AM1714 INJECTED
I.P IN NAIVE RATS
% MPE
100
75
50
25
0
30
100
300
1000
DOSE AM1714 (μg)

FIG.5

300μg I.P AM251 IN NAIVE RATS DID NOT REVERSE THE EFFECT OF 300μg I.P AM1714

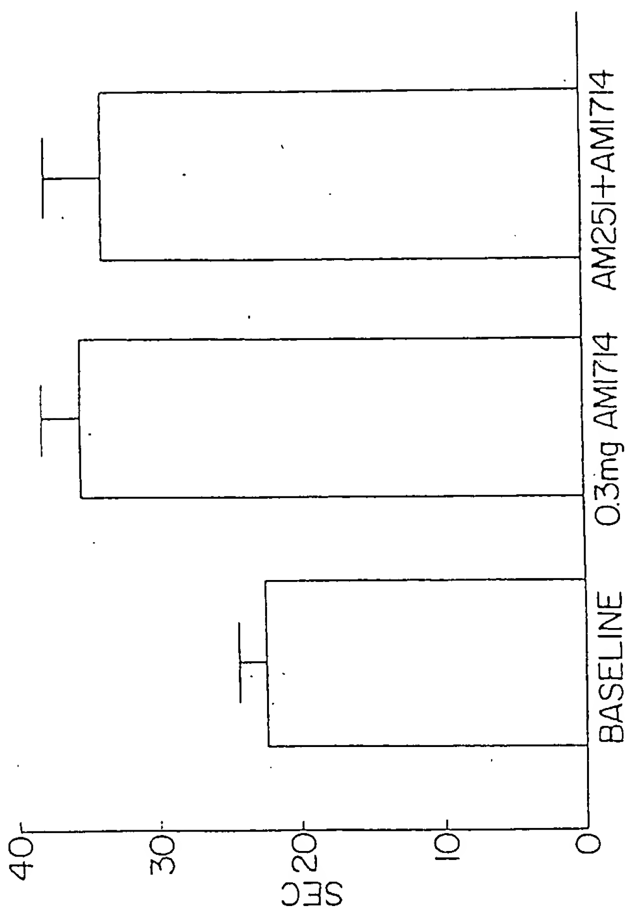


FIG.6

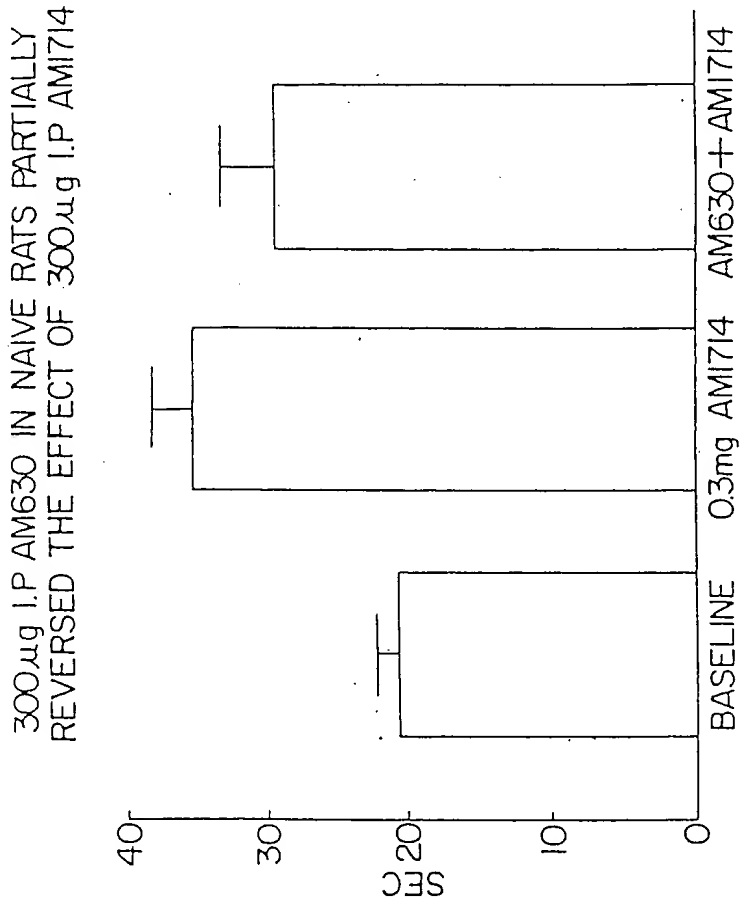

300µg I.P AM630 IN NAIVE RATS PARTIALLY
REVERSED THE EFFECT OF 300µg I.P AM1714
SEC
0
10
20
30
40
BASELINE
0.3mg AM1714
AM630+AM1714

FIG.7

WIN 55,212-2 (CBI/CB2 AGONIST) IMPAIRS MOTOR FUNCTION BUT AMI714 DOES NOT WHEN GIVEN INTRAPERITONEALLY

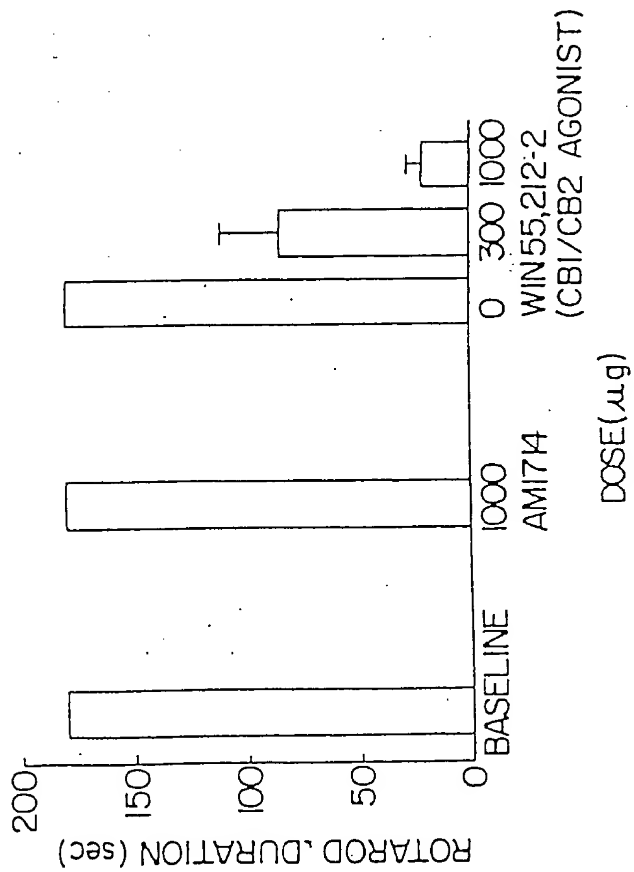


FIG. 8

300µg INTRAPLANTAR AM630 BLOCKED THE ANALGESIC EFFECTS OF 300µg I.P ADMINISTERED AM1714 IN NAIVE RATS

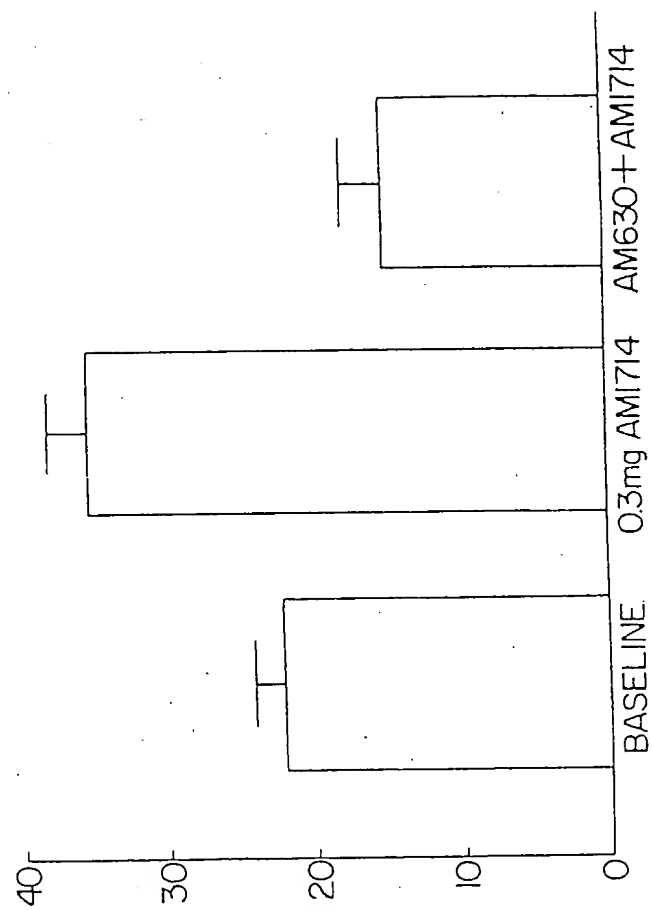


FIG. 9

300μg INTRAPLANTAR AM251 DID NOT BLOCK THE ANALGESIC EFFECTS OF 300μg I.P ADMINISTERED AM1714 IN NAIVE RATS

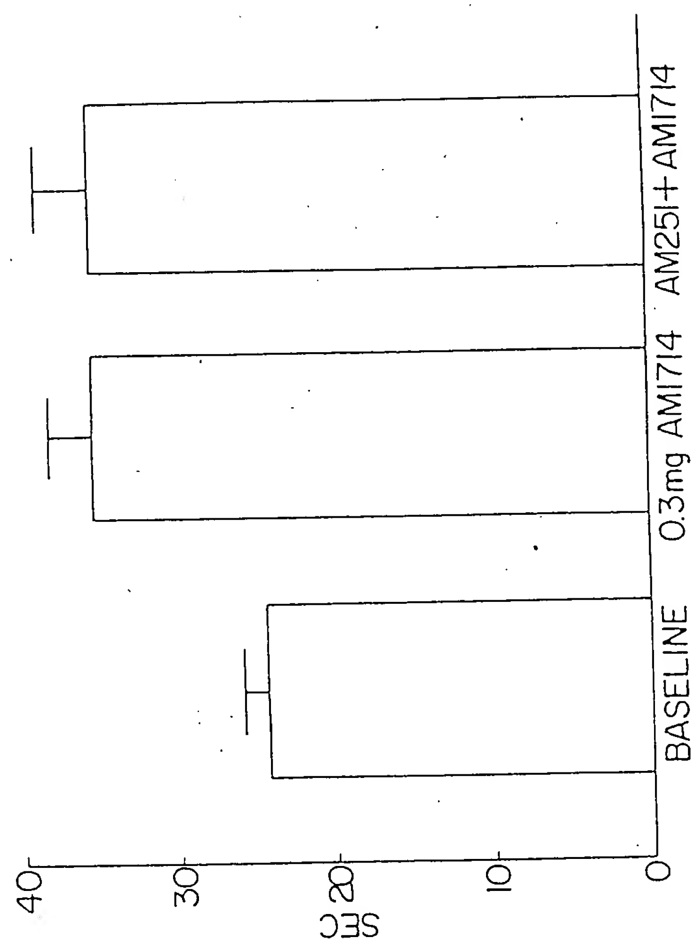


FIG. 10

300µg INTRAPLANTAR AM630 BLOCKED THE ANALGESIC EFFECTS OF 300µg I.P ADMINISTERED AM1714 IN NAIVE RATS

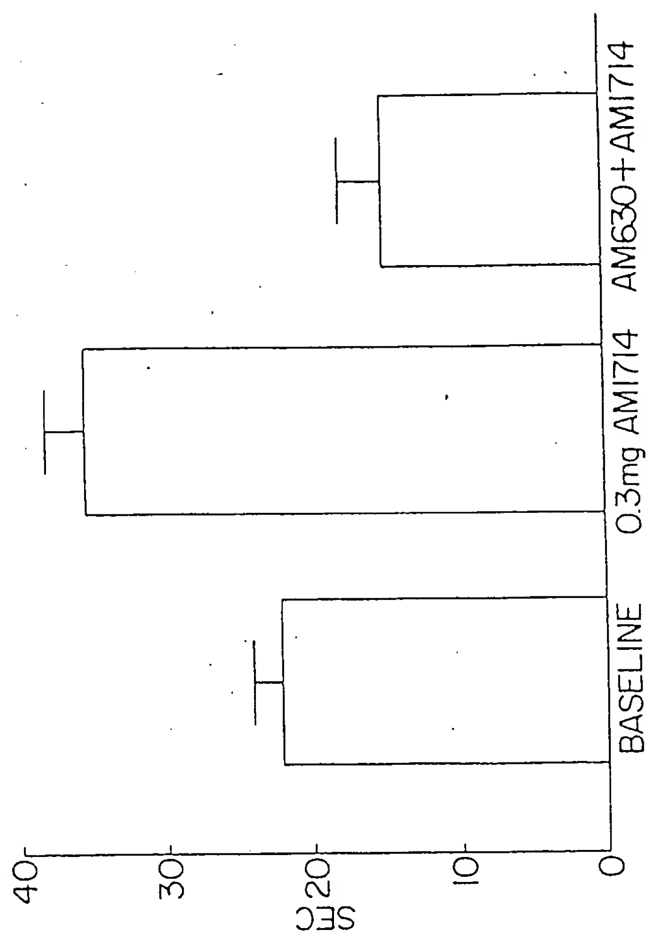


FIG. 11

300µg INTRAPLANTAR AM251 DID NOT BLOCK THE ANALGESIC EFFECTS OF 300µg I.P ADMINISTERED AM1714 IN NAIVE RATS

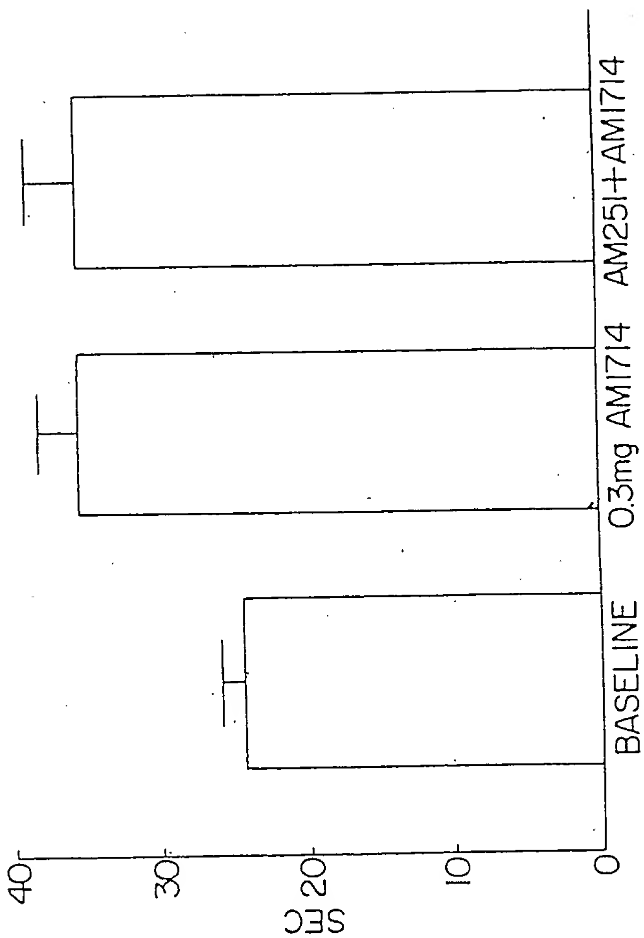


FIG.12

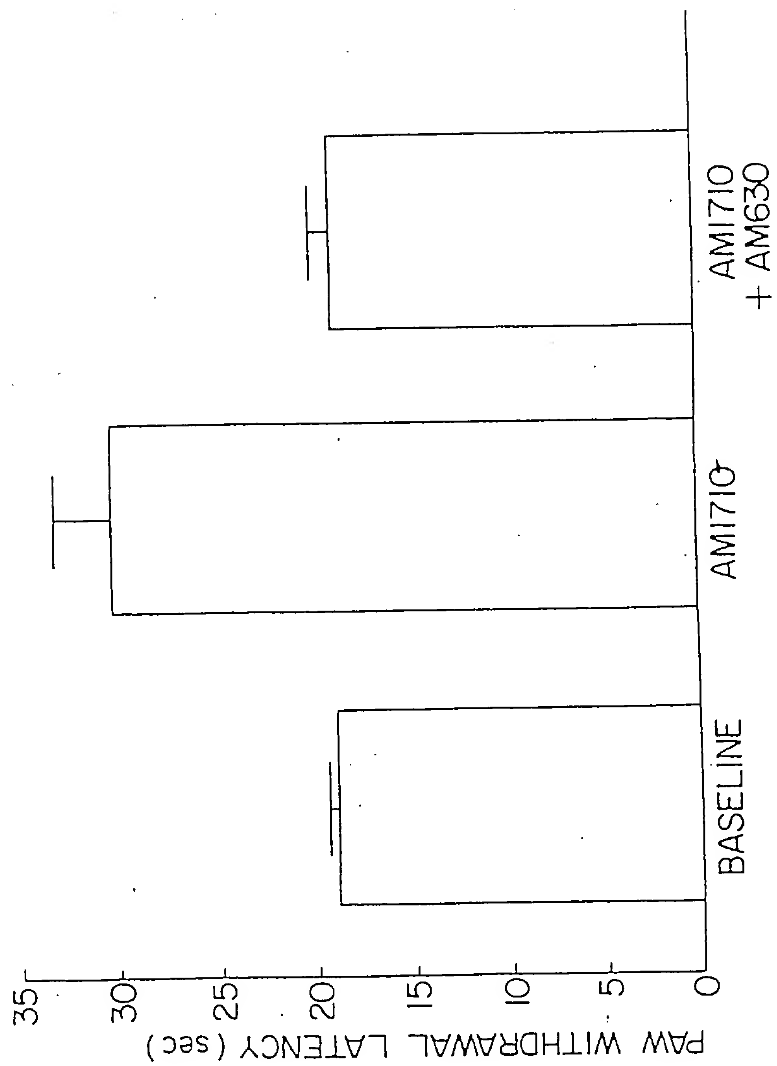

PAW WITHDRAWAL LATENCY (sec)
35
30
25
20
15
10
5
0
BASELINE
AM1710
AM1710
+ AM630

FIG.13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/28818

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : A01N 43/16; A61K 31/35; C07D 311/78
US CL : 514/455; 549/280
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 514/455; 549/280

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

REGISTRY, HCAPLUS, USPATFULL, HCAOLD, BEILSTEIN, MARPAT structure search

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 3,573,327 A (MIYANO) 30 October 1971, see abstract	1-5

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

30 JANUARY 2001

Date of mailing of the international search report

27 MAR 2001

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